MANTLE SOURCES OF LOW-TI LAMPROITES FROM THE MESOZOIC COLLISION ZONE OF THE ALDAN SHIELD, EAST SIBERIA: GEOCHEMICAL AND SR-ND-PB ISOTOPE EVIDENCES.

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Introduction

Ultrapotassic-mafic and-ultramafic rocks from the western and central part of the Aldan shield (East Siberia) were first described as lamproites by Mironuk(1960), and subsequently studied by Vladikin (1985), Tomshin et al. (1986). Bogatikov et al. (1986), and Mahotkin (1991). On the basis of major element variations and their mineral assemblages, the Aldan lamproites have been divided into 2 major groups: (1) agpaitic lamproites from the Murun massif, Molbo River (Olekma Granite-greenstone Archaean block) and Lomam massif (Timpton enriched amphibolites granulite-gneiss Archaean block); (2) miaskitic lamproites from the Central Aldan area and Chompolo-Amga River (Central-Aldan granulite-gneiss Archaean block) (Fig.1). Both lamproite groups are strongly depleted in Ti and other high-field-strength elements (HFSE) relative to large-ion-lithophile elements (LILE) and LREE compared with an average lamproite (Bergman,1987). In this respect the Aldan lamproites resemble other collision-related potassic rocks from convergent margins. In this paper geochemical and isotopic data for the Aldan agpaitic and miaskitic lamproites are used to infer the mineralogy and chemistry of their mantle source regions, and to assess the processes responsible for the relative HFSE depletion of the Aldan lamproites.

Geological Setting

The Aldan Mesozoic lamproite magmatism is a product of collision-related tectono-magmatic activity along the south-east margin of the Siberean platform which collided with mobile lithospheric blocks of the East Asian plate in the Mesozoic (Fig.1). The lamproitic magmatism occurred far to the north of the Mesozoic collision front according to the zonation of Mesozoic magmatism. The lamproites occur mainly along the northen slope of the Aldan Shield and their separate occurences comprise a discontinuous belt over 500 km long and ~150 km in width. Within this area emplacement of the lamproites, together with other Mesozoic alkaline and subalkaline magmatism in the western and central part of the Aldan shield, was related to local Mesozoic extension between several north-east oriented uplifted crustal blocks. This tectonism formed a weakly developed wide-spread shear zone within the Aldan Shield (Fig.1). The Mesozoic lamproites were erupted in two stages: (1) 130-136 Ma (Neocomian) and (2) ~120 Ma (Aptian) (Mahotkin,1989; Mues, et al.,1994). In most areas lamproite magmatism was contemporaneous with potassic alkaline magmatism (leucitites, phonolites, phlogopite-pyroxenites and related dunites, missourites, shonkinites, alkaline syenites, alkaline granites) and subalkaline magmatism (minettes, absarokites, trachytes, syenites, monzonites).

Rock types and mineralogy

Among the miaskitic lamproites of the Central Aldan area there are three rock series: (1) sills and dikes (~133 m.a.) of the differentiated ultramafic-mafic lamproites intruding the Yakokut and Inagli massif and Verhni-Yakokut Jurassic depression in the central part of this area; (2) pipes and related dikes (~130 m.a.) of mafic lamproites intruding in the Nizhni Yokokut eruptive field (5 pipes) and Nizhni Seligdar eruptive field (12 pipes); both eruptive fields are situated in the northern part of the Central Aldan Sheild; (3) pipes and related eruptive dikes and sills (~120 m.a.) of intensive altered potassic ultramafic breccias whose compositions are close to mica kimberlite or olivine-mica ultramafic lamproite (Yagodka, Zvezdochka, Mrachnaja pipes and another 16 pipes and dikes).

The Verhni-Yakokut lamproites are madupite family lamproites, and the magmas have experienced flow-differentiation and olivine accumulation yielding Ol-Di-Phl ultramafic lamproites in the central part of dikes and the lower zones of sills that are up to10 m thick. The Yakokut ultramafic lamproites contain large rounded and euhedral phenocrysts of Mg-rich olivine (25-40 vol.%) and diopside (5 vol.%); microphenocrysts of olivine, diopside, and Cr-spinel included in olivine and diopside phenocrysts. Their coarse- to fine grained groundmass consists of diopside (10-15 vol.%), poikilitic plates of phlogopite (20-28 vol.%), pseudoleucite altered to orthoclase (16-20 vol%), oxides and glass altered to amphibole, talc and chlorite.).

The mafic lamproites of the Nizhni Ykokut eruptive field are subdivided into 3 groups: olivine-phlogopite-diopside mafic lamproites (very diamond-poor Kayla pipe); phlogopite-diopside mafic lamproites (Lyzhnaaja pipe near the northern border of the Raybinovy massif), and olivine-diopside mafic lamproites (from the Ryabinovaja pipe intruding the central part of the same alkaline massif). All of these lamproites are porphyritic rocks with rounded or euhedral phenocryst and microphenocrysts of olivine (10-20 vol.%), diopside (7-15 vol.%) and phlogopite (12-15 vol .%) for the Kayla lamproites, olivine (1-7 vol.%), phlogopite (20-35 vol%), and diopside (10-25 vol.%) for the Lyzhnaja pipe, and olivine (10-25 vol.%) for Raybinovaja pipe. Their groundmass assemblages consist of diopside + phlogopite (biotite) +/- pseudoleucite +/- sanidine (with ~2 wt.% FeO) + oxides +/- altered glass. Among the heavy mineral concentrates Cr-spinels and zircons are predominant, but picroilmenite is absent. Xenocryst spinels are enriched in Cr_2O_3 (59-63.0 wt.%).

Among the agpaitic lamproites of the Olekma area there are 3 rock types: olivine-diopside-phlogopite mafic lamproites (dykes, Murun); diopside-phlogopite-richterite mafic lamproites (dykes, Murun); olivine-phlogopite mafic lamproite (dyke, Molbo).

Agpaitic ultrapotassic-ultramafic rocks of the Lomam intrusion include phlogopite wherlites, phlogopite missourites and K-richterite pyroxenites, which on the basis of mineral and melt inclusion compositions, exhibit close similarities to the Murun agpaitic lamproites.

Temperature and oxygen fugacity

The Yakokut ultramafic lamproite melts have high homogenisation temperatures (1190-1245 °C) that, however are lower than maximum estimates from Ol-Sp equilibria (1050-1350 °C) due to the effects of dissolved magmatic fluids. The estimated fO2 for the Yakokut melts is NNO+(0.5-1.5 lg.un.). The Raybinovaja pipe mafic lamproite estimates are T(Ol-Spl)=1120 °C and T(Cpx-Phl) = 1100-1200 °C, and fO2=NNO. The Lyzhnaja pipe mafic lamproites have T(Cpx-Phl)=790-900 °C, T (Ol-Spl)= 650 °C, fO2=NNO-0.5 lg.un. The Lomam ultrapotassic ultramafic rocks have melt inclusion homogenisation temperatures ranging from 1050 to 1230 °C T(Ol-Spl)=900 °C, and fO2=NNO+1 lg.un.

Geochemistry and isotope compositions

The Central Aldan miaskitic lamproites have more primitive composition than those of the Murun and Molbo agpaitic lamproites, and the latter are relatively enriched in HFSE, LREE and LILE. Mantle-normalised trace element patterns for all Aldan lamproites exhibit the negative Ta-Nb, Zr-Hf and Ti anomalies (Fig. 2). In a plot of Nb/Th versus Nb the lamproites fall within the field of island arc basalts (IAB). The Aldan lamproites have higher ε_{Sr} and lower ε_{Nd} than the present day bulk earth and they plot in the enriched quadrant of the ε_{Sr}-ε_{Nd} diagram, exhibiting a sub-vertical trend (Fig. 3) which coincides with that of the Wyoming and Montana lamproites. This suggests the Aldan lamproites contain a contribution from old, LREE-enriched lithospheric mantle with a Nd model age $NdT_{(Dm)}$ in the range 1.81 to 2.21 b.a. for the Central Aldan and Lomam lamproites, and from 2.55 to 2.66 b.a. for Murun and Molbo lamproites. Sr model ages $SrT_{(Ur)}$ for all Aldan lamproites range from 233 m.a. to 1262 Ma. The Aldan lamproites have similar age corrected Pb isotopic ratios to other anorogenic potassic rocks in that they plot to the left of the geochron in a 207Pb/204Pb versus 206Pb/204Pb diagram. They extend from the field of South African Group II kimberlites (207Pb/204Pb = 15.47, 206Pb/204Pb = 17.42) to the field for the unradiogenic Smoky Butte lamproites (207Pb/204Pb = 15.25, 206Pb/204Pb = 16.77). 208Pb/204Pb values are also unradiogenic and span the range 37.18 - 38.08. These unusually unradiogenic Pb isotope ratios require a mantle source characterised by long-term relatively low U/Pb and Th/Pb values.

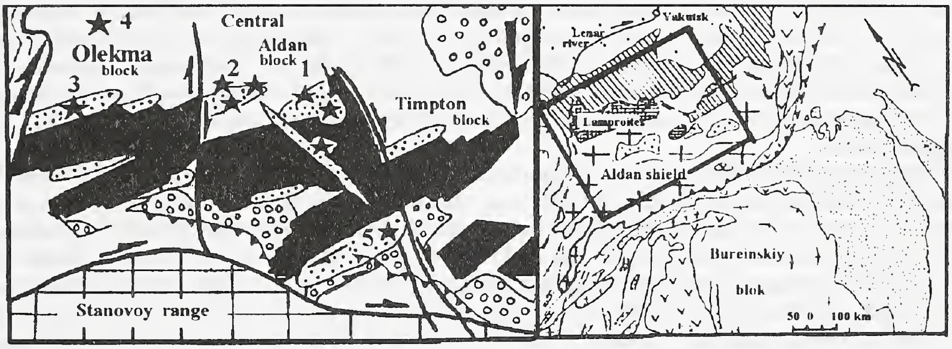
Discussion of magma sources.

The mineralogy and depths of mantle source regions for the Aldan lamproites have been inferred on the basis of their primary melt compositions in relation to high-pressure phase diagrams from Foley (1986, 1993), and Wallasse & Carmichael (1989) Fig. 3. Primary melt compositions have been estimated using appropriate olivine-melt equilibria: Fo93-94.4, Kd=0.28-0.29, and fO2 conditions defined by Irvine (1979) and Ghiorso and Carmichael (1980). The primary melts of both agpaitic and miascitic lamproites are enriched in MgO (14-22.6 wt.%), K2O (3.6-8.6 wt.%), SiO2 (45.6-52.3 wt.%) and depleted in Na2O (0.8-1.6 wt.%). They plot near peritectic points of Phl, En, Fo at 30-55 kbar (fig.3) suggesting that the Aldan lamproites are small-degree partial melts derived from the vicinity of the mechanical layer of the Aldan lithospheric mantle. The composition of the Cental Aldan primary melts plot near the peritectic points of Phl, Di, Fo phases at 30-55 kbar and inside the Di phase field.. The agpaitic primary melts lie along the Fo-Phl cotectic at 20-45 kbar outside the Di field. These data suggest that mantle source for the Central Aldan miascitic lamproites was phlogopitic lherzolite that melted under a slightly elevated CO_2 pressure, whereas the source for the agpaitic lamproites was phlogopite harzburgite that melted under predominantly H_2O pressure. The inferred depleted character of the Archean lithospheric mantle of the Olekma and Timpton Archaean block is consistent with the quite voluminous abundance of mafic rocks (including komatiites) in both blocks relative to the Central Aldan block.

Based on the experimentaly determined Ti-saturation levels in basaltic melts (Green and Pearson,1986; Ryerson and Watson, 1987), the marked relative HFSE depletion in the Aldan lamproites is unlikely to be due to the presence of a residual Ti-bearing phase during melt generation and melt ascent through the lithosphere during the

Mesozoic. The Ti-saturation equlibria temperatures for the Aldan ultramafic-mafic primary melts at 40-50 kbar and fO_2= NNO are ~900-950°C which is much lower than their liquidus temperature (1230-1245°C). Thus the Aldan lamproite HFSE depletion reflects that of the Aldan lithospheric mantle. In accordance with the NdT(DM) age data the HFSE depleted character of the Aldan lithospheric mantle may have developed contemporaneous with the Archaean cratonization (~2.85 b.a.) during widespread granite-gneiss development in the Olekma granite-greenstone block, or alternatively, contemporaneous with the Early Proterozoic reactivity process (2.05-1.95 b.a.) that produced extensive collisional granite-gneiss magmatism and amphibolite grade metamorphism within the Central Aldan and Timpton Block areas.

The Late Archaean or Early Proterozoic subcontinental mantle of the Aldan shield was inhomogeneously enriched by fluids characterised by high LREE/HFSE and LILE/HFSE ratios, and subsequently between the Upper Proterozoic and Upper Mesozoic the mechanical layer of this mantle was enriched mainly in LILE with a low Rb/Sr ratio. Any potential influence of a high-Ti hot asthenospheric source component was restricted due to the Early Proterozoic and Mesozoic collisional setting of the Aldan shield. The Aldan lamproite melt generation was initiated by decompression of the lithospheric mantle in the deep levels of its mechanical layer after reducing the Mesozoic collisional stress.



★ — Lamproite occurences: 1-Central Aldan area, 2- Chompolo, 3-Murun massif, 4-Molbo river, 5- Lomam massif

Fig.1

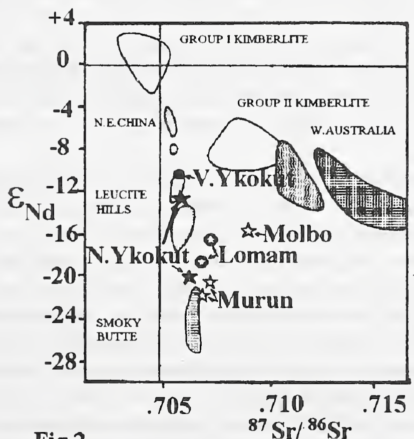
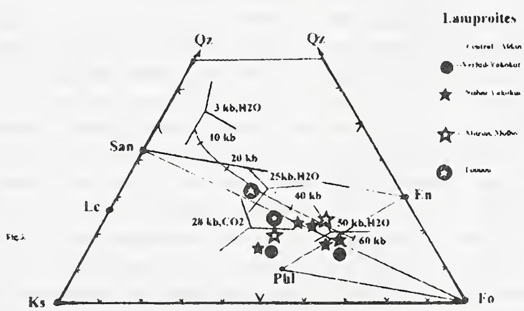


Fig.2.



Aldan primary melt positions relative to Ol+Opx+Phl+Lq peritectic points at 10-60 kb after of Foley (1993)